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METHODOLOGY FOR RESEARCH-INFORMED TEACHING AND LEARNING IN ELECTRONICS ENGINEERING

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Abstract

In the fast-growing era of Engineering and Technology, in particular, the Electronics Engineering modules/subjects have become a challenging area nowadays to educate the students in this COVID-19 scenario. This present research proposes a methodology to help the students improve their learning by including practical laboratory and research. This proposed methodology will assist students in developing creative concepts and electronic devices for advanced device applications related to Electronics Engineering. The main emphasis is Research Informed Teaching (RIT) and learning with design projects centered on the Bachelors, Masters, and Doctorate students. In addition, this work discusses the research projects, teaching methodology, etc., which can be helpful for academicians and students.

Keywords

Electronics Engineering, Research- Informed Teaching, Diversity and Inclusion

1. Introduction

A disease named coronavirus (COVID-19) came into force at the end of 2019, which is spreadingglobally, and the World Health Organization (WHO) declared it a pandemic in March 2020. To date, the world has paid a high toll in this pandemic regarding human lives lost, economic repercussions, and increased poverty (Ciotti et. al., 2020). The comparative selection between continuing or endingthe lockdown with an optimal control model encompassing health and economic outcomes was examined (Caulkins et. al., 2020). The shutdowns impacted students, including mental health consequences of much concern because depression, stress, and anxiety affect the student's learning ability. The challengesfaced by students during this period (Megan K. Youmans, 2020). (Gelles et. al., 2020) A qualitative case study where they interviewed students (in 2020) to explore how they adapted to the transition of remote learning. The university-based empirical work in groups to learn about research can be replaced by an online mechanism while maintaining task value and acceptable self-efficacy (Higgins et. al., 2021). (Muller et. al., 2021) Some have explored university educators' eLearning practices and future adoption intentions. Thorough interviews with various educators were conducted. The educators had limited online experience before the COVID-19 emergency online learning and expressed preferences for in-contact sessions.

Pre-service teachers' skill and knowledge acquisition regarding Evidence-Informed Teaching (EIT) help to build more promising beliefs about the utility of various theories and evidence (Kiemer and Kollar, 2021). (Dierdorp, 2021) It has been investigated whether the impact of a Science, Technology, Engineering, and mathematics (STEM) teacher's EIT approach using the suggestion of flipping the classroom research improves students' enthusiasm and if this methodology allows students to accomplish better. (Welsen et. al., 2020) Some have analyzed the Science and Engineering students' usage and attitudestoward e-books when using their available e-readers, which include computers or portable devices.

The key deliberation is enabling the safe return of as many students and teachers as possible whilekeeping physical distancing (Sheikh et. al., 2020). (Bubou et. al., 2017) It has been suggested that recent challenges are maintaining pace with technological dynamism, high attrition, and quality teaching and learning requiring multifaceted tactics. (Annie and Shemim, 2019) An itinerary has been outlined for constructiveassociations between research and teaching to be pursued by individuals and Higher Education (HE) institutions for advancing in RIT.

In higher educational institutes, in particular, the Electronics Engineering subject specializing in Micro-Electronics and design projects becomes challenging to teach and to learn for both academicians and students (Peter and Srivastava, 2020, Moorthy and Srivastava, 2022). Regarding the COVID-19 pandemic, various institutes, university classes, and laboratories shifted to remote learning. In multiple cases, these requirements intersected inproductive ways with updated modules and course content for virtual environments (Won et. al., 2020). (Kiernam, 2020) Some have considered the best performance for teaching in online mode by examining academicmoves taken for environmental studies courses during the COVID-19 situation.

(Srivastava, 2020, Dargar and Srivastava, 2019) They have summarized teaching methods including bachelor's design projects with technological integration for the electronic engineering cluster students. However, engineering education was primarily focused on that work. To overcome these issues, the author has suggested some features to speed up research-informed teaching, mainly towards Electronics Engineering and design projects. The author's teachingphilosophy is the delivery of an impressive and technically sound lecture with engaging content, which is imperative to render such a lecture engaging, informative learning that is easily understood by the students being taught at the time. Doing so allows the students to gainknowledge and learn. It shows that students can become innovative entrepreneurs, not just the user.This paper has been organized as follows. Section 2 has the process followed for Research-Informed Teaching (RIT). Section 3 has the proposed methodology for research-informed teachingand learning. Finally, Section 4 concludes the work and recommends future aspects.

2. Process Followed for the Research-Informed Teaching

In this scenario, it is challenging to deliver face-to-face lectures and perform in laboratories for advanced research. Also, contribution towards the research/supervision of international standards, including inter-disciplinary aspects, is a nightmare nowadays. Collaboration with colleagues in the university to develop joint research projects and secure the funding required for the long-term growth of the research activity is a challenging aspect, as various travel restrictions and frequent meetings with peers. Also, scientific or professional conferences were on halt. In addition, students'involvement in becoming technical members of various professional and technical societies, suchas the student chapter, has reduced drastically. Engagement in organizing the workshops, seminars,and conferences converted to an online medium is a complex case for the people of rural areas orfor the non-technical person. The author has proposed some suggestions to overcome these issuesin this research work.

The author's philosophy of teaching is that delivering an impressive lecture with engaging contentis imperative to render such a lecture engaging, informative learning that is easily understood by the students being taught at the time. In the author's opinion, leaching and learning is a continuous process, and it is two-way communication between the learner (students) and educator(lecturer). Thus, from the author's perspective, the process of learning is constitutive of various aspects, such as:

- Identifying the level of the student's background knowledge.
- Taking a few lectures to revise the pre-requisite for the recent subject.
- Present the core module lectures with impressive content (PPT, chart, overhead projector, smart board, etc.) so that it will attract students' attention.
- Providing the lecture notes and other required materials to the students after the lecture.
- Providing extra lectures for students deemed weak is done with the view of making these students comfortable with the module.
- To understand the learning, a regular mock test or surprise test can be organized so the lecturer can understand students' learning capability.
- Design projects are helpful to understand the theories.
- Providing detailed solutions of the tests and exams and marks in a short time.
- A session for the explanation about the exam question answers.
- Getting feedback from the students taught in the modules in question.

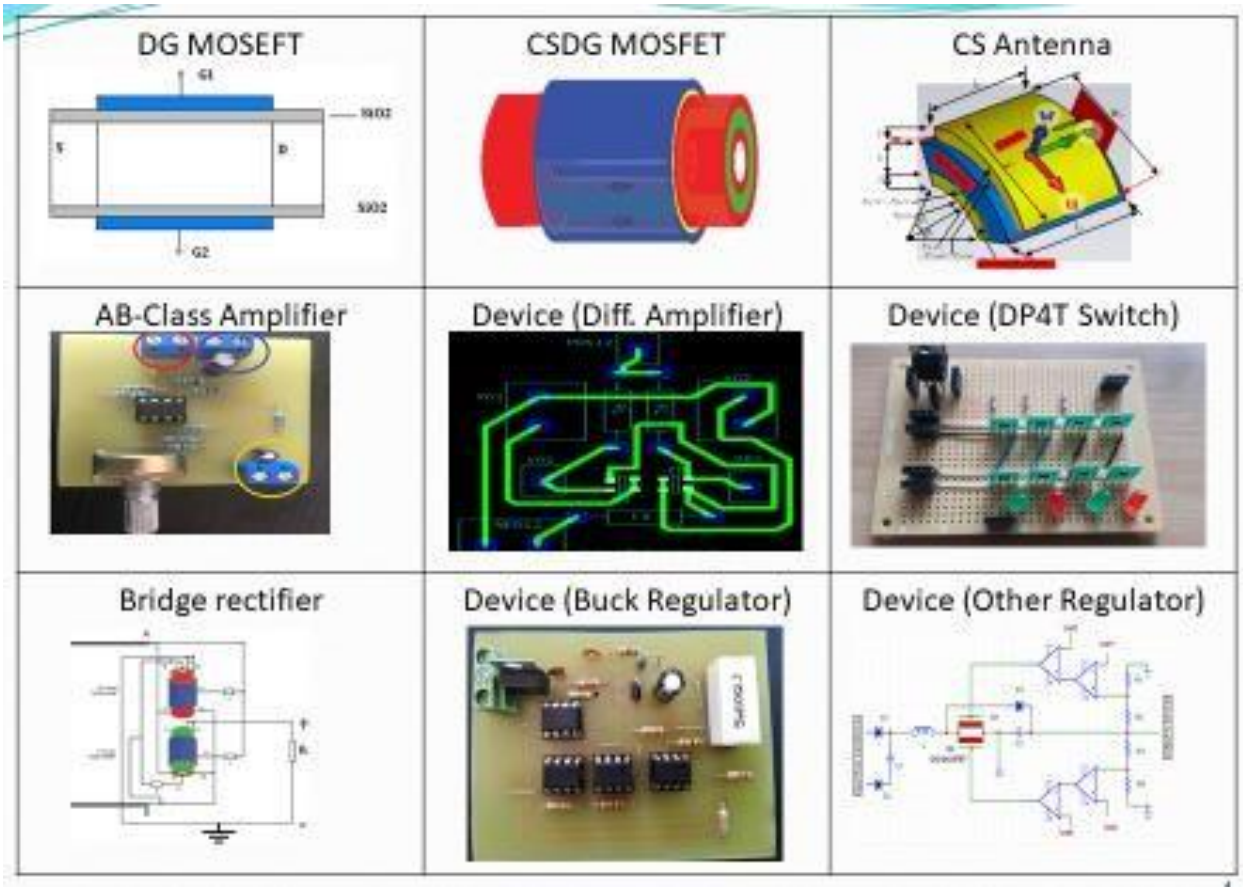
In this scenario, delivering face-to-face lectures and performing in laboratories for advanced research is challenging. Also, contribution towards the research/supervision of international standards, including inter-disciplinary aspects, is a nightmare nowadays. Collaboration withcolleagues in the university to develop joint research projects and secure the funding required forthe long-term growth of the research activity is a challenging aspect, as there are various travel restrictions and frequent meetings with peers. Also, scientific or professional conferences were onhalt. In addition, students' involvement in becoming technical members of various professional and technical societies, such as the student chapter, has reduced drastically. Engagement in organizingthe workshops, seminars, and conferences converted to an online medium is a complex case for people of rural areas or non-technical people. To overcome these issues, the author has proposed some suggestions in this research work.

3. Proposed Methodology for Research-Informed Teaching and Learning

To gain momentum toward research-informed teaching and learning, the following steps can befollowed:

Stage 1: Students should be informed about the prospective employer (if they are job seekers)or company (if they are entrepreneurs) related to their field of study, e.g., microelectronics/electronics / mobile companies, etc. It will create interest in the students so theycan select a goal after their studies. For example, Fig. 1 shows various research aspects.

Fig. 1: *Perspective Research Opening Areas*



(Source: Srivastava, 2014, Pillay and Srivastava, 2020)

Stage 2: The news related to the latest technology can be informed to the students, which givesan idea to the students that the subjects they are going to study in the present semester are related and in line with the latest research on the market, which will be helpful to materialize these in terms of product

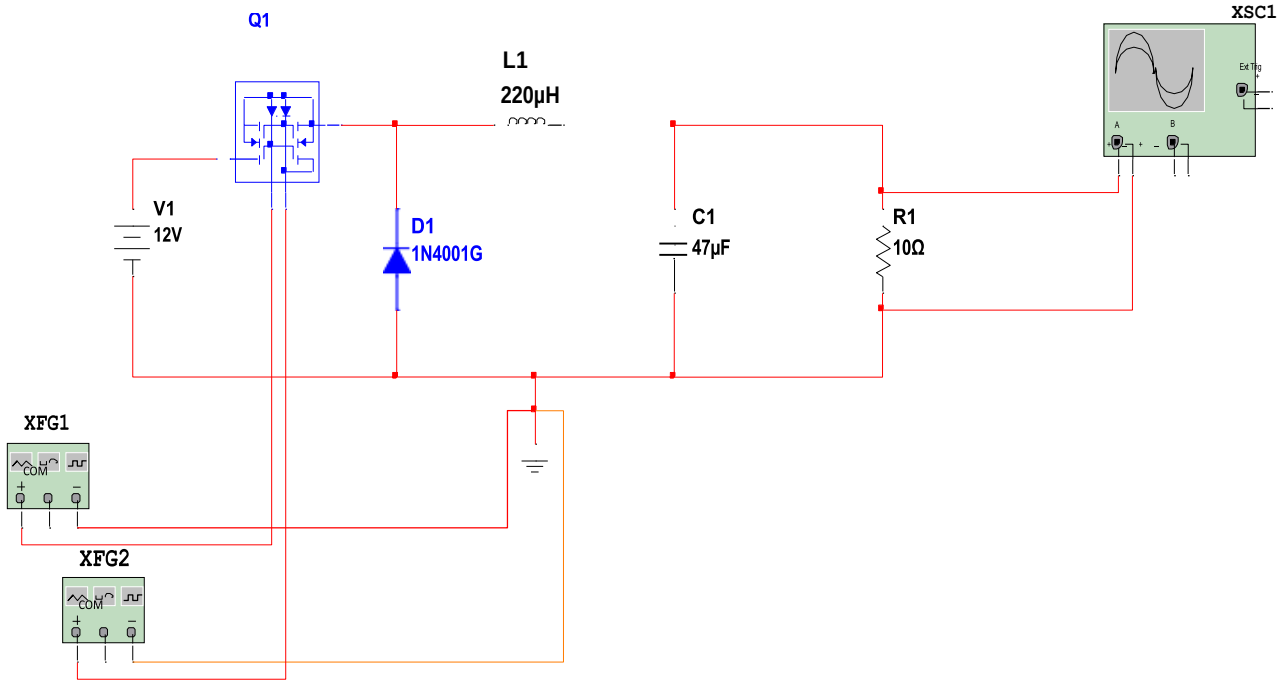
design (shown in Fig. 1). These can be accompanied by handouts, PPT presentations, and online materials, and during covid-19, shifting to Kaltura, Moodle, Zoom, Team, Google Meet, etc. (in line of teaching and research methodology)

Stage 3: Revision should be done for each subject at the start of the semester, such as engineering mathematics; electrical and electronic principles; communication systems, devices & circuits; integrated circuits, Bipolar Junction Transistor (BJT), Metal Oxide Semiconductor Field Effect Transistor (MOSFET), etc. (Sedra and Smith, 2014). In addition, the research work should also be done inthe same manner. For example, circuit designing for simulation, mathematical analysis for the research work, simulation methods using Assembly language, Keil, SUPREME, MATLAB, PSpice, VEE Pro (Agilent), Lab View, ModelSim (VHDL and Verilog HDL), Xilinx, Microwind, Micro-Cap, ADS, etc., and prototype model as shown in Fig. 2.

Stage 4: Some specific questions should be asked to the students at regular intervals to check their learning, such as (example for microelectronics-related subjects): why Cylindrical Surrounding Double-Gate (CSDG) MOSFET, what is CSDG MOSFET, what you will do to improve this device, and how to design CSDG MOSFET with its advantages, comparisons with the existing models, etc. Thereafter, allow the students to select any two or more parameters so that they can show their creativity to nurture this device further.

The author encourages his students to be curious, address theory and problems critically, exerttheir common sense, and expand their lateral thinking abilities. In most lectures, he gives a few short answers to questions so that students can participate actively and remain attentive during the lectures. Another critical factor here is that during these short-answered questions (active lecturing), students can interact with their classmates who are in proximity. This encourages cohortcohesion and creates a sense of identity for students, thus reducing students' alienation resulting from being isolated. The author believes in a student-centered approach, providing students with individual assistance and dealing promptly with student issues by liaising directly with the student, program supervisor, and other college personnel as required.

Fig. 2: *(a) Circuit for Simulation, (b) Mathematical analysis snapshot, (c) Simulation analysis, and (d) Fabrication*



(a)

$$\eta_{\text{conduction-DG}} = \frac{V_o}{V_o + 1 - \frac{t_{\text{on}}}{2T}} = \frac{3.35}{3.35 + 1 - \frac{0.15\ \mu\text{s}}{2 \times 10\ \mu\text{s}}} = 77.14\%$$

The switching power has bene calculated using (9) as:

$$P_{\text{switching-DG}} = \frac{I_o V_{\text{dc}}}{12}\left(\frac{t_{\text{on}} + 2t_{\text{off}}}{T}\right) = 14.85\ \text{mW}$$

Therefore, the total losses using (12) can be calculated as:

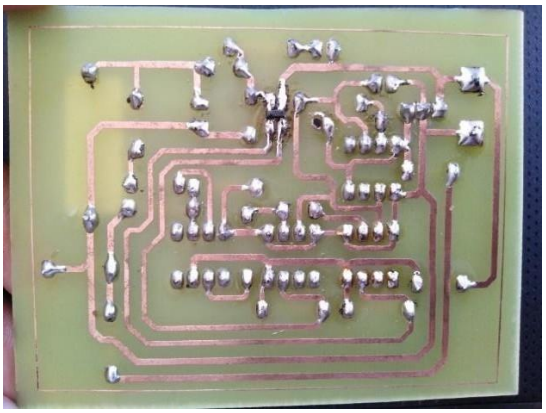
$$\text{Losses}_{\text{Total-DG}} = I_o\left[1 - \frac{t_{\text{on}}}{2T}\right] + \frac{I_o V_{\text{dc}}}{12}\left(\frac{t_{\text{on}} + 2t_{\text{off}}}{T}\right) = 313\ \text{mW}$$

However, the efficiency of this designed circuit can be realized using (14):

$$\text{Efficiency}_{\text{DG}} = \frac{V_o}{V_o + 1 + \frac{V_{\text{dc}}(t_{\text{on}} + 2t_{\text{off}})}{12T}} = 76.48\%$$

(b)

(c)



(d)

(Source: Leeuw and Srivastava, 2021)

Stage 5: Various fundamental theories can be explained to the student, such as: in the Double-Gate (DG) MOSFET, the gates are only on the two sides of the substrate; these gates can be extended on the all-around the device and designed like a cylinder; and thereafter its benefits should be explained. It has less contact area with the board as compared to the other MOSFETs (thereafter, its comparative disadvantages and benefits should be explained), its switching speed analysis with benefits should be explained; also, future applications in electronic devices can be discussed. In addition to these, the instructor can provide extra lectures for students deemed weakand is done to make these students comfortable with the subject.

Stage 6: However, the electronic device application and demands from the consumer side are increasing day by day. Therefore, the research should also be advanced in line with these objectives, which forces the universities to upgrade the syllabus and course contents. In line with this, the course curriculum should be revised regularly, say 2-4 years' time. It can be done via adding a new course/subject (e.g., nanotechnology, 5IR, 6G, AI, ChatGPT, etc.), making any traditional compulsory subject optional, to make space for a new trends-related subject. Moreover, a lecturer should be extensively involved in improving the modules/programs at an individual leveland within a program team. This has been made to rethink the curriculum and to develop sound, relevant, and innovative programs and modules. It can also enhance the teaching and research process.

Stage 7: It will be an interactive idea to form the design project at an individual or group level.For example, fabrication of CSDG MOSFET, quantum effect analysis (for channel length of 10 nm range), hot-carriers effect (device degradation for high power and high-frequency applications),

various materials effect on devices e.g. Hafnium di-Oxide (HfO_2), a high dielectric, with superb adhesion to metals such as Aluminum and Silver; performance achieved by the switchcan be further improved by using better technologies, footprint saving, pick and place effort analysis for Integrated Circuit (IC) design (Srivastava, 2009, Srivastava, 2015, Srivastava, 2017, Srivastava et. al., 2010). As a lecturer, it is my responsibility to create and oversee a comprehensive classroom so that every learner can feel comfortable participating in theconversation. One of the effective ways to encourage students of different backgrounds is to engage them with peer dialog on one platform. During this process, students learned from each other and appreciated the diversity. The author has various occasions to inspire students to pursue studies (undergraduate)/ higher studies (postgraduate) in Electronics Engineering, for example, bycreating a social media platform for group discussion (as per university guidelines); during this group project, students interact with each other, and in addition to the technical contents, they learnabout the diversity and inclusions such as: diverse culture, disability, ethnicity, heritage, language,traditions, country of origin, etc. (Bernstein et. al., 2020, Mapes et. al., 2020, Sanger and Gleason, 2020).

Stage 8: The authors' philosophy regarding diversity and inclusion is that all students and researchers should be given equal opportunity. The author works with various students, researchers,faculty, and staff regardless of their diverse culture, disability, age, ethnicity, gender, heritage, language, race, religion, sexual orientation, socioeconomic status, traditions, country of origin, etc. (Gates, 2018, Singh and Srivastava, 2018, Krulatz and Christison, 2023). With these experiences, the author has learned how to effectively connect with people ofvarious backgrounds different from his own. The author believes diversity inclusion in the lectureroom and research group is critical for academics.

Stage 9: Regarding the postgraduate student, the author initially explains the roles, functions,and responsibilities of the supervisor & the student, ethical issues related to the research & supervision processes, and university rules & regulations for postgraduates. Thereafter, plan a program for regular meetings. Then, the discussion of the requirements of the project and its feasibility starts. Finally, a standard proposed work plan gets prepared once the student has understood what is expected of them. This allows students to integrate their theory subject knowledge with the proposed project.

Stage 10: Now, various Universities and industries are opening their door (due to the minimized effect of Covid-19); therefore, a Work Integrated Learning (WIL) approach can be introduced as a course curriculum at the undergraduate level (Fleming and Zegwaard, 2018, Dean et. al., 2020, Pretti et. al., 2020, Isdaryanti et. al., 2023) .It will give students a view of how theindustries work. It will

boost the student's ability to learn effectively with a hands-on experimentalapproach.

Stage 11: In between the course or in the regular semester, faculty can apply for funding from various external sources such as research foundations, etc., which are specific to countries. To sustain the research external funding is required, which also includes the peer's review of the proposed/designed projects. The author is engaged in solving the problems arising from advanced technologies with students by providing the students' necessary guidance. This entails a detailed process of probing into how a specific problem in research can possibly be solved. After resolvingthe defined issues, the author represents his university through the research outcomes at various international conferences in South Africa and international universities. In this manner, he builds national and international contacts and participates in networks with colleagues to exchange information and collaborate with them in future research fields.

Stage 12: Finally, during the exam, a blended approach can be followed, which means 50% can be organized in the examination hall, and 50% can be arranged online. It can vary as per the curriculum of the particular university.

4. Conclusion and Future Scope of the Work

In this work, the author has proposed a methodology for research-informed teaching and learningfor Electronic Engineering. This work is mainly centered on undergraduate and postgraduate students involved in Electronics Engineering research. It discussed the teaching methodology to Bachelor, Master, and Doctorate students, including diversity and inclusion.

These are the suggested steps. In addition, various other steps can be adopted as the situation changes due to the shift from online to face-to-face teaching. In addition, this work has a direction,which can be used as a template to design the course curriculum of a specific subject.

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